

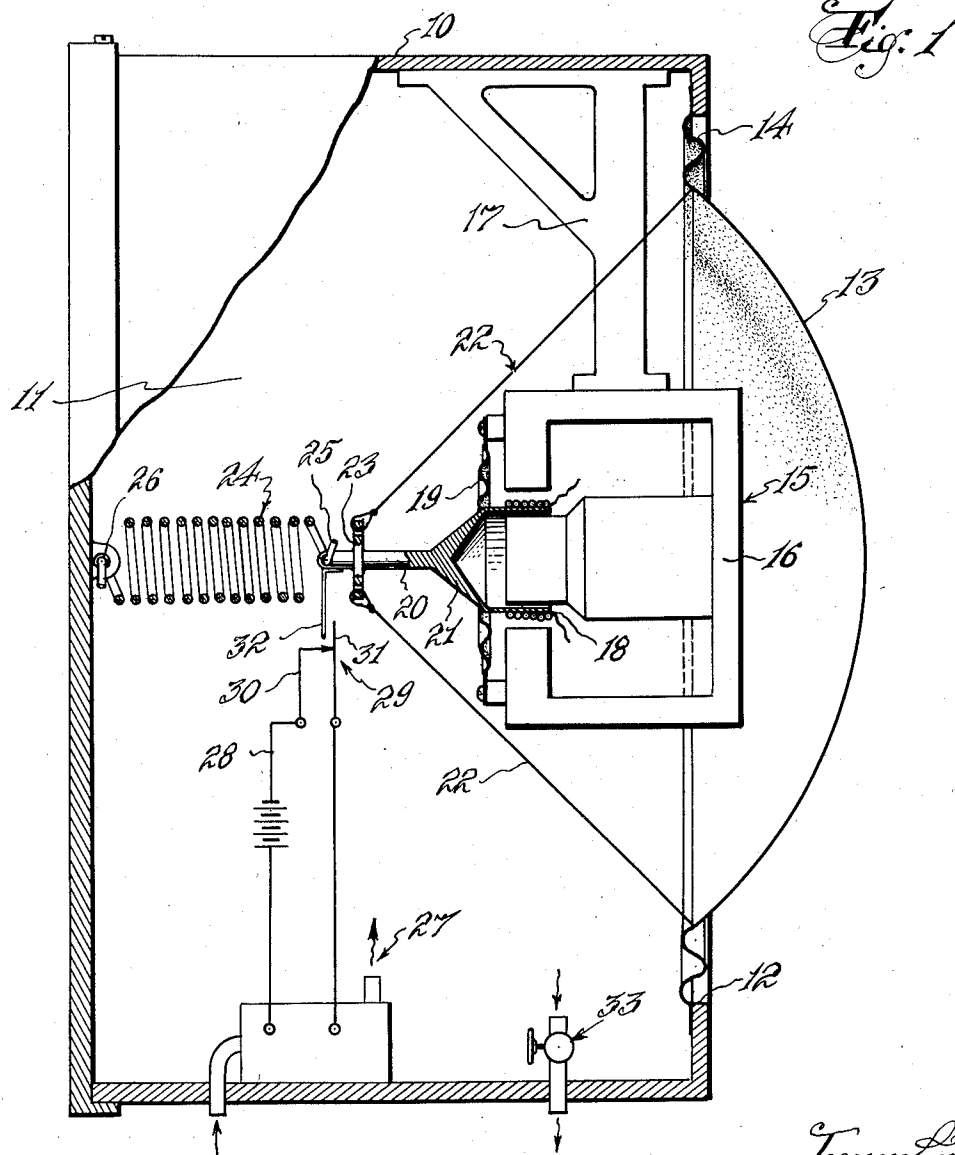
Aug. 5, 1958.

P. J. BROWNSCOMBE
LOW FREQUENCY LOUDSPEAKER

2,846,520

Filed Nov. 22, 1955

3 Sheets-Sheet 1



Inventor:
Philip J. Brownscombe.

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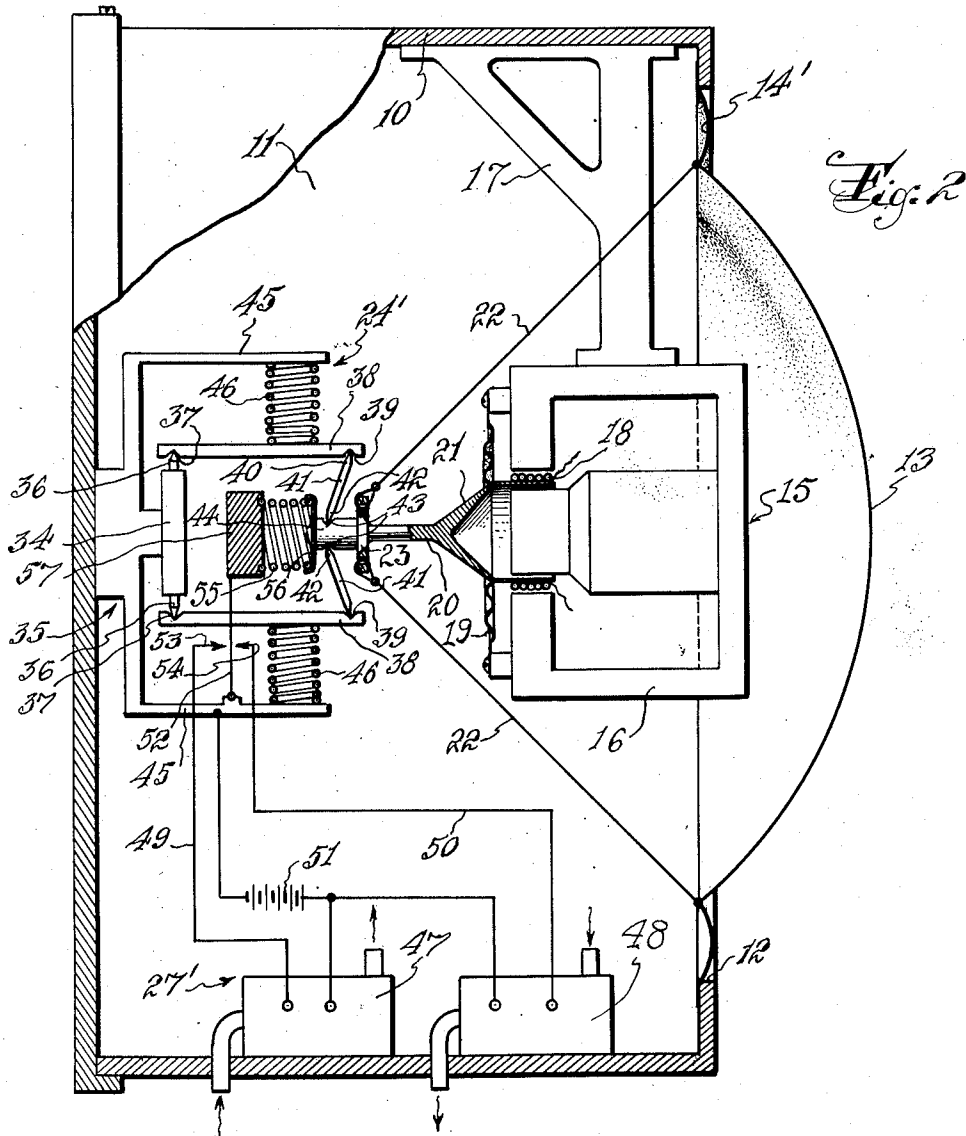
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

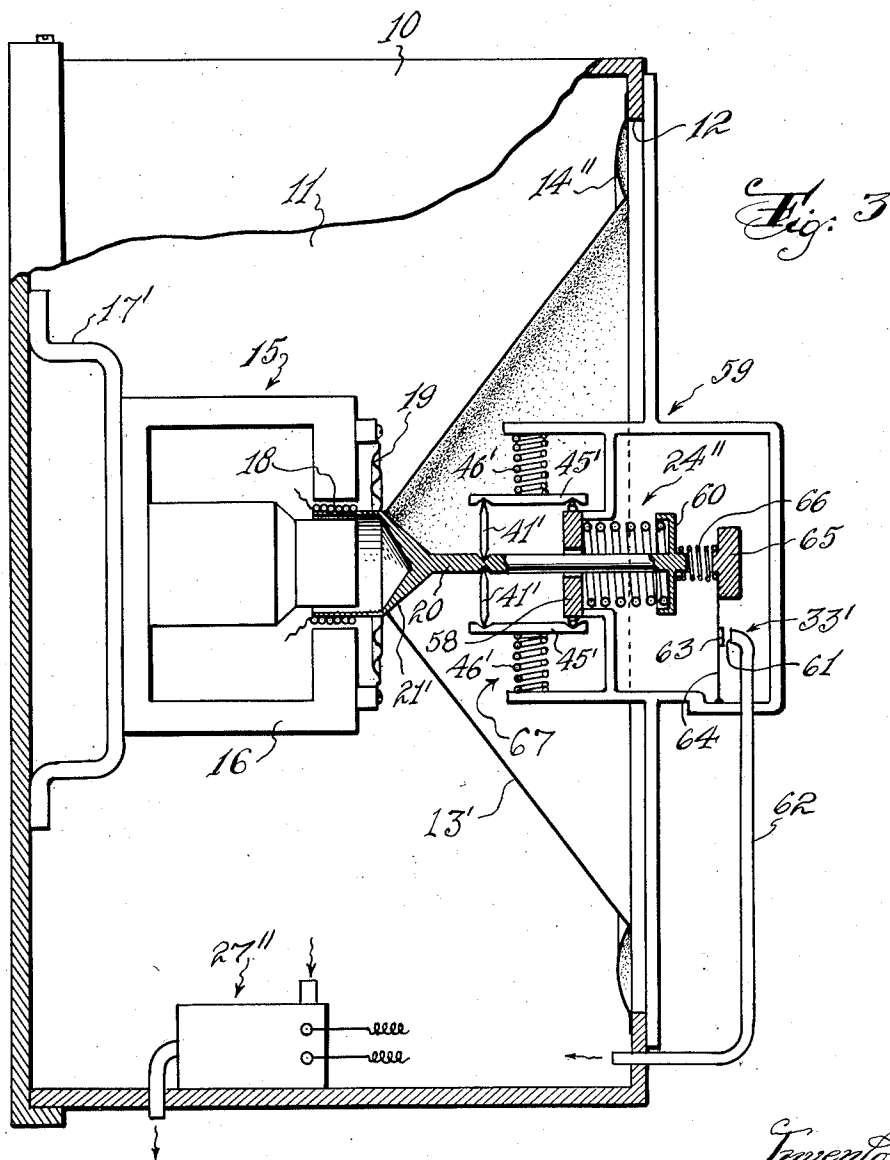


Fig. 3

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LOW FREQUENCY LOUDSPEAKER

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Application November 22, 1955, Serial No. 548,374

21 Claims. (Cl. 179—115.5)

The invention relates to loudspeakers such as are used in connection with radio and television receivers and record players, and has particular reference to those speakers that are designed to radiate relatively large amounts of power at very low frequencies.

Prior to my present invention, it has been impracticable to use desirably light-weight, thin, flexible sound radiating diaphragms in low frequency loudspeakers due to the deformation which occurs under the forces arising from normal vibration. These forces may arise from air pressure conditions or from inertia of the diaphragm. It therefore has been the practice to employ comparatively heavy, rigid diaphragms which usually have been conical in form and made of stiff paper.

Since diaphragm deformation usually has been caused by air pressure conditions, brief explanation of this cause may be justified at this point.

When reproducing low frequency sounds, a large volume of air must be displaced at each cycle. This requires, in a direct radiator speaker, a diaphragm of large area and substantial amplitudes of vibration. In order to prevent radiation from one side of the speaker from cancelling that from the other side, it is necessary to use some type of baffle or enclosure. I prefer to completely enclose one side of the diaphragm. However, if an enclosure of moderate size is used with a diaphragm of large area, this results in relatively high air pressure differences being developed between the two sides of the diaphragm and exposure of the latter to correspondingly high forces which, in speakers of conventional construction, tend to bend or buckle the diaphragm. That is why it has been necessary in the past to make the diaphragm sufficiently thick and heavy to withstand the forces to which it is subjected in operation, especially those reversing stresses set up when there is a higher air pressure on one side of the diaphragm and this higher pressure condition alternately shifts from one side to the other with the normal vibratory movement of the diaphragm.

Obviously, a heavy diaphragm and particularly one of rigid structure does not possess the low inertia and sensitivity to sound vibrations desired for use in a low frequency speaker.

Actually, the most efficient diaphragm for a low frequency speaker, provided it can be maintained in completely distended form at all times, is one of semi-spherical or dome shape and made of very thin, light, inelastic material. Therefore, it is the primary object of the present invention to provide a loudspeaker structure which makes it practicable for the first time to employ a diaphragm of this most desirable type.

Briefly, I attain that object by mounting the diaphragm with one side arranged to radiate into a completely enclosed air space and the other side facing the outside atmosphere, and by providing means to insure constant exertion against the concave side of the diaphragm of air pressure slightly in excess of that to which the convex side is subjected. Due to these vital provisions, the thin diaphragm will be maintained at all times in its completely

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distended dome shape and free from any reversing stresses. Means is provided also to cause the diaphragm to vibrate as a whole under the influence of the driving means therefor.

Due to the fact that the transducer which drives the diaphragm causes the latter to vibrate in opposite directions from a mid-position that, in conformity with the structural design characteristics of the loudspeaker instrument, would be substantially stabilized if it were not for the effects of air pressure variations, it is desirable that the average position of the diaphragm under the influence of pressure changes shall coincide as closely as practicable to its designed vibrational mid-position. It is considered to be in the interest of efficient operation to preserve the stability of the design characteristics by striving for proper coordination between the vibrational mid-position of the diaphragm and its average position during cyclic displacements as caused by pressure variations. It, therefore, is a further object of the invention to provide means for automatic regulation of the air pressure differential in a manner to prevent objectionable displacement of the diaphragm from its normal vibrational mid-position at any time despite the disturbing tendencies of changes in ambient temperature and atmospheric pressure.

Other objects, features and advantages of the invention will become apparent as the following specific description is read in connection with the accompanying drawings, in which;

Fig. 1 is a semi-diagrammatic longitudinal vertical sectional view of a simplified embodiment of the invention;

Fig. 2 is a similar view of a modified form of the invention; and

Fig. 3 is a similar view of a further modification.

Referring now in detail to the drawings, wherein like reference characters designate corresponding parts in the several views, a simplified embodiment of the improved loudspeaker is disclosed in Fig. 1.

There are certain conventional structural components of the loudspeaker that are common to all three illustrative embodiments and they will be described first. Primarily, there is the rigid enclosure, or housing, 10 which confines an enclosed air space 11. The front wall of enclosure 10 has a preferably circular opening 12 in which the sound reproducing diaphragm 13 of the speaker is mounted in marginally sealed juncture with the edge of said opening by a surround 14, which latter is of a construction to resist radial displacement of the diaphragm from centered position but to permit free axial vibration under the influence of driving unit, or transducer, 15. In the embodiment represented in Fig. 1, surround 14 is of corrugated construction in accordance with conventional practice. Transducer 15 preferably comprises the usual magnetic structure 16, which is supported rigidly inside enclosure 10 by suitable means such as bracket 17, and voice coil 18. The latter is separately supported in the gap between poles of magnetic structure 16 by the conventional, axially yieldable, annular centering member 19, which, like surround 14, preferably is of corrugated construction.

The operation of transducer 15 is quite similar to that of those employed in conventional speakers. A varying current from any suitable source, such as a phonograph and its amplifier (not shown), is passed through voice coil 18. Because coil 18 is in a strong magnetic field, a force is created which will drive the coil in axial motion corresponding to the electrical current vibrations. By mechanically connecting coil 18 to diaphragm 13 in a sufficiently rigid manner, the latter will be caused to vibrate as a whole and sound will be radiated from its surfaces. This connection may be accomplished in the manner illustrated, which includes the attachment of coil 18 rigidly to an axially centered rod 20 through the

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medium of cup-shaped member 21 or other equivalent means. The rear end of rod 20 is shown as being connected to the periphery of diaphragm 13 by plural circumferentially spaced tension members 22, which may be wires or cords, whose rear ends may conveniently be affixed to a concentration ring 23 carried by said rod. To complete the assembly and assure proper tension in members 22 for a rigid connection between rod 20 and diaphragm 13, spring means 24 is added to exert constant rearward tensioning pull on rod 20. In the embodiment of the invention illustrated in Fig. 1, spring means 24 is in the form of a simple compliant helical spring having one end attached to the rear end of rod 20, as at 25, and its opposite end anchored in the rear wall of enclosure 10, as at 26. Centering member 19 serves to hold rod 20 and supported coil 18 in concentric relation to transducer 15.

As already stated in the introductory part of the specification, it is preferred to use the highly efficient dome-shaped diaphragm shown in Fig. 1 instead of the usual conical diaphragm. This dome-shaped diaphragm 13 may be made of a thin, flexible, inelastic membrane for the functional advantages to be gained thereby. In fact, it has been found that draftsman's tracing paper is quite suitable for this purpose. However, a diaphragm of this selected type requires means to maintain its natural form at all times. For this purpose, pumping means 27 has been provided to pump air into enclosure 10 from the outside atmosphere. The pressure applied in this way to enclosed space 11 tends to make diaphragm 13 assume that shape which encloses the greatest volume, i. e. its naturally semi-spherical, completely distended shape. It may be mentioned at this point that an important advantage of the pressure-distended condition of diaphragm 13 is the fact that a large radiating surface may be constructed of very much less material and hence of much lighter weight than one which must be capable of withstanding bending loads.

In accordance with my invention, it is intended, as previously expressed, that there shall be a constant difference between the pressure exerted on the inner surface of diaphragm 13 and that to which the outer surface is subjected (atmospheric pressure). This is to insure that there shall be no reversing stresses imposed upon diaphragm 13. Consequently, because diaphragm 13 of the loudspeaker disclosed in Fig. 1 is outwardly convex and inwardly concave, it is necessary in this particular embodiment to maintain an internal pressure that is slightly above atmospheric pressure.

It also is my purpose to regulate the internal air pressure so that the average balanced position of diaphragm 13 under the opposed forces of spring means 24 and the air pressure differential shall coincide as closely as possible to the midposition between limits of its vibrational excursions when being driven by transducer 15. Despite the restraining effect of spring means 24, diaphragm 13 would be forced axially forward far beyond the desired average position if pumping means 27 were permitted to operate continuously. Therefore, it is preferred to utilize an electrically operated pump that can be controlled readily to stop the pumping action when diaphragm 13 has reached its desired average position. To this end, the electric circuit 28 of pumping means 27 has been provided with a normally closed switch 29 comprising stationary contact 30 and a movable contact 31 that will be forced away from contact 30 to open the circuit by actuating means, such as the arm 32 provided on rod 20, when the desired forward displacement of diaphragm 13 has been reached.

Due to the likelihood that pumping means 27 cannot be stopped at precisely the instant diaphragm 13 reaches its vibrational mid-position, means has been added to reverse the direction of displacement of the diaphragm when that has been excessive. That means is constituted by a valved atmospheric vent 33 provided in a wall

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of enclosure 10. Vent 33 produces a small but steady leakage of air from enclosed space 11 in order to restore diaphragm 13 to its vibrational midposition. If the retrograde movement of diaphragm 13 becomes too much, actuating arm 32 will permit movable contact 31 of switch 29 to engage stationary contact 30 and thereby again close circuit 28 and cause pumping means 27 to resume operation. It is quite likely that pressure-displacement of diaphragm 13 will proceed in continuous cycles of small magnitude forward and rearward of its average position, but this displacement will not be serious because the pumping cycles will be so much slower in frequency than the lowest frequency of sound, which is several cycles per second.

Instead of a valved vent 33, the leakage means could take the form of a valve controlled by another switch contact (not shown), but that should not be required. In fact, the unavoidable leakage in any loudspeaker that occurs through diaphragm diffusion and permeable joints probably would suffice to return the diaphragm automatically from excessive forward displacements.

Whenever a reduction in air pressure within enclosure 10 occurs from any cause other than the intentionally controlled leakage produced by valved vent 33, such for instance as may be caused by changes in ambient temperature or in atmospheric pressure, switch-actuating arm 32 will be moved rearward until it closes circuit 28 and causes pumping means 27 to bring the internal pressure back to normal.

The operation of the simplified form of my improved loudspeaker will now be described. Even while the communications circuit in which voice coil 18 is connected is not transmitting signals, pumping means 27, switch 29 and valved vent 33 will be functioning automatically to maintain the constantly distended shape of diaphragm 13. This means that diaphragm 13 will be displaced forward and backward in relation to an average position that closely approximates the diaphragm position in which voice coil 18 is centered between the magnetic poles of transducer 15 and in which surround 14 and centering member 19 are designed to be under no axial tension in either direction. This position may be termed the "design vibrational mid-position" or just the "vibrational mid-position," because, when signal transmission occurs, vibrational excursions of diaphragm 13 will commence and end at this position due to the design characteristics of the mounting arrangement. Although virtually synonymous, the terms "mid-position" and "average position" have been used to differentiate between the respective design electrically vibrational mean position and the mean position of pressure-produced displacements.

When the communications circuit again becomes operationally alive, the transmitted signals will cause voice coil 18 to vibrate in opposite directions from its mid-position. Due to the rigidity of tension members 22 under the pull of spring means 24, diaphragm 13 will vibrate in synchronism with voice coil 18. Consequently, sound waves will be radiated by diaphragm 13. Moreover, because of the extreme lightness of diaphragm 13 and the unusually large area presented by its semi-spherical shape, high fidelity reproduction of sounds of low frequency will result.

Referring now to Fig. 2 of the drawings, it will be observed that the loudspeaker construction illustrated therein differs from that disclosed in Fig. 1 principally in the type of spring means and pumping means employed to preserve the desired distended form of diaphragm 13. A less important modification is the simplified form of surround for the diaphragm, which occupies the arc of a single circle instead of being corrugated, it having been discovered that the new means of maintaining diaphragm 13 in distended condition results in a centrally balanced suspension that makes corrugations unnecessary. It is practicable to make surround 14' of the same material

as diaphragm 13, such as thin paper, and to make these two components integral in structure.

Spring means 24' adopts the structure and functional operation of the "negative stiffness" device disclosed in my copending application which bears the Serial Number 479,902 and was filed January 5, 1955. In its application to the present invention in substitution for the simple helical spring 24 disclosed in Fig. 1, the negative stiffness type of spring means 24' serves to offset the normal or "positive" stiffness produced by the enclosed air volume 11 acting on diaphragm 13. When, in the course of normal operation, diaphragm 13 is caused to move in a vibratory manner by transducer 15, pressure changes due to this motion occur within the enclosed air volume 11. These pressure changes are to be distinguished from those produced by cyclic operation of pumping means 27'. For example, when diaphragm 13 moves in its rearward excursion from mid-position toward enclosed volume 11, the air therein is reduced in volume and the pressure rises in accordance with well known laws. This pressure increase, which is added to the pump-created pressure value at the moment, reacts upon diaphragm 13 to produce a force that opposes movement thereof and therefore results in reduced effectiveness of sound radiation, particularly at low frequencies. This effect is well known in the art.

In a manner which will be more fully understood after the physical structure of the negative stiffness type of spring means 24' has been described, this spring means is adapted to serve in a triple capacity. While maintaining the rigidity of the connection between diaphragm 13 and rod 20 by keeping tension members 22 taut, it also offers general opposition to the pump-created pressure effect on said diaphragm, and, as its third function, partially cancels the change in pressure, or positive stiffness, within enclosed volume 11 resulting from axial vibrational motion of the diaphragm.

From the several species of the negative stiffness device disclosed in my previous application cited above, I have chosen for my present purpose the one represented in Fig. 2 of the present disclosure, but it is to be understood that I am not to be restricted to this particular embodiment.

As shown in Fig. 2, a rigid bar-like member 34 is mounted by means of supporting bracket 35 on the rear wall of enclosure 10 to extend diametrically with respect to the axis of rod 20. This member 34 has knife-edge bearings 36—36 at its opposite ends to engage transverse inwardly facing grooves 37—37 provided in the rear end portions of a pair of levers 38—38 which extend parallel to the axis of rod 20 on diametrically opposite sides thereof. The front end portions of levers 38—38 have similar inwardly facing transverse grooves 39—39 for engagement with the knife-edge bearings 40—40 at the respective outer ends of a pair of toggle struts 41—41 whose inner ends have knife-edge bearings 42—42 to engage transverse grooves 43—43 provided in an enlarged head 44 formed on the rear end of rod 20. Forwardly presented arms 45—45 extend rigidly from supporting bracket 35 in outwardly parallel relation to levers 38—38 and are located in the common axial plane of said levers and rod 20. Compression springs 46—46 respectively are interposed between each corresponding arm 45 and the corresponding lever 38 to maintain the latter in secure engagement with the respective knife-edge bearings 36 and 40 of corresponding member 34 and toggle strut 41, and also to exert radially inward forces on said lever. In this manner, both toggle struts 41—41 are continually subjected to inward forces in directions radial to the axis of rod 20.

Whereas in my prior invention disclosed in application Serial Number 479,902, the toggle struts are designed to extend precisely radial to the rod which corresponds to rod 20 of my present disclosure when the sound radiating diaphragm is in its vibrational mid-position, the rela-

tive arrangement of the respective grooves 39—39 and 43—43 in levers 38—38 and head 44 of rod 20 in the present invention is such that toggle struts 41—41 are inclined with their radially inner ends disposed axially in rear of their outer ends. As a result of this arrangement, springs 46—46 constantly exert axial components of their forces rearward on rod 20 and these force components will be transmitted to diaphragm 13 through the medium of tension members 22—22. Consequently, each time diaphragm 13 moves in one of its excursions rearward of its vibrational mid-position, the components of the forces imposed upon rod 20 will cancel part of the "positive stiffness" exerted by the air pressure within enclosed volume 11 due to the fact that the said force components are acting in the same direction as the instant diaphragm movement. Due to the changing degree in inclination of toggle struts 41—41 as diaphragm 13 moves progressively further rearward in its excursion, the cancelling components of the forces exerted by springs 46—46 will be proportionate to the degree of diaphragm displacement and will continually balance the forces exerted by air pressure, or positive stiffness.

The pumping means 27' to maintain the desired pressure differential between enclosed volume 11 and the atmospheric side of diaphragm 13 differs from the corresponding pumping means disclosed in Fig. 1 in that it is adapted to reduce the internal air pressure by positive valving action whenever diaphragm 13 becomes so far displaced outward that it is caused to vibrate about a position further away from the enclosed volume than its design mid-position. To this end, electrically operated pump 47 and valve 48 are provided. Pump 47 and valve 48 are respectively connected in parallel branches 49 and 50 of an electric circuit supplied by source 51. A movable switch contact 52 connected in common to both circuit branches is shifted by extensive rearward and forward movements of rod 20 under the influence of air pressure into alternate engagement with stationary contacts 53 and 54 that are included respectively in the circuit branches 49 and 50.

In order to prevent undesired circuit-closing operation of movable switch contact 52, such as otherwise could be caused by the opposite thrusts of rod 20 due to sound radiating vibration of diaphragm 13, said movable contact is operatively connected to the rear end of said rod through the medium of a preferably helical spring 55. This spring 55 is interposed between a cupped disk 56 affixed to rod 20 and a block-like member 57 of considerable mass, which is attached to the free end of movable contact 52. The inertia of member 57 is such that it will move forward or rearward only in response to the slow, steady displacements of rod 20 which result from air pressure changes and thus will not be affected by sound vibrations of diaphragm 13.

Movable switch contact 52 normally will be in inoperative position substantially midway between stationary contacts 53 and 54 whenever diaphragm 13 is in its design vibrational mid-position. In the event that the pressure differential, or ratio of inside pressure to atmospheric pressure, becomes undesirably low, movable switch contact 52 will move rearward into engagement with stationary contact 53, whereupon the branch electric circuit 49 of pump 47 will be closed and the latter will start operating to restore the pressure differential to its desired ratio. When this occurs, contact 52 should have reached its neutral, open-circuit position represented in Fig. 2. If the internal pressure should rise sufficiently to move diaphragm 13 forwardly beyond its vibrational mid-position, movable contact 52 will engage stationary contact 54 and thereby close circuit branch 50 of valve 48 to open the latter to the atmosphere. As a result of this action, valve 48 will exhaust air from the interior of enclosure 10 until diaphragm 13 has receded to its desired mid-position. These cycles of pressure regulating pumping and valving actions will be going on continually and

yet slowly as compared with the higher frequency sound vibrations of diaphragm 13.

In the two illustrative embodiments of the invention disclosed in Figs. 1 and 2, the respective sound radiating diaphragms 13 have been outwardly or forwardly, bulging and have been maintained in distended condition by having the air pressure in enclosed volume 11 always slightly higher than the opposed pressure of the atmosphere. In Fig. 3, a third embodiment is shown wherein the diaphragm 13' is in the conventional form of a cone but made of desirably light material. This diaphragm 13' is arranged with its convex side facing inward, or rearward, toward enclosed volume 11. The same advantages of a large diaphragm of low mass, which is not subjected to bending stresses, may be obtained by operating with the air pressure inside the enclosure below atmospheric pressure. In this case, the stiffness contributed by the enclosed air volume 11 is less than in the usual situation prior to the present invention in which atmospheric pressure existed on both sides of the diaphragm.

Structurally, the loudspeaker represented in Fig. 3 differs from the embodiments disclosed in Figs. 1 and 2 principally in the reversed arrangement of its component parts. Transducer 15 is now mounted by bracket 17' on the rear wall of enclosure 10 instead of on the front wall. Conical diaphragm 13' is located entirely inside the opening 12 in the front wall of enclosure 10, and surround 14'' is inwardly convex instead of being outwardly convex as in the embodiment disclosed in Fig. 2. The apical portion of conical diaphragm 13' is joined in a hermetically sealed manner to an impervious cup 21' on the rear end of rod 20. This cup 21' is rigidly united with centering member 19 and voice coil 18 and co-operates with surround 14'' in completing the sealing of front wall opening 12.

Pumping means 27'' of this third embodiment of the invention is intended to operate continuously in a direction to exhaust air from enclosed space 11 instead of to introduce air as in the previously described embodiments. A modified valve means 33', which will be described in detail presently, serves to admit air to enclosed space 11 at appropriate intervals to counteract the reduction of pressure in said space to an excessive degree by pumping means 27''.

Rod 20 in this third illustrative embodiment is mounted for longitudinal reciprocation in apertured member 58 supported by a spider frame 59 that is affixed to the front wall of enclosure 10 in covering, but not sealing, relation to opening 12 therein. Adjacent to its rear end, rod 20 has a cupped disk 60. Spring means 24'' is interposed between this disk 60 and apertured member 58 and is designed to offer the desired resistance to rearward pressure on diaphragm 13' by the atmosphere.

The valve means 33' to which brief reference has been made includes a fixed seat 61 provided at one end of an air conduit, or tube, 62, which has its opposite end in communication with the interior of enclosure 10. Seat 61 of valve means 33' faces rearward toward enclosure 10 in axial parallelism with rod 20. A movable valve member 63 is mounted in operative relation to valve seat 61 by supporting means such as the swinging arm 64 which has its lower end pivotally connected to frame 59. The upper end of arm 64 is affixed to a block-like member 65 of considerable mass which is supported by rod 20 through the medium of a spring 66 of preferably helical form. The inertia of member 65 is such that it will move forward and rearward only in response to the slow, steady displacements of rod 20 which result from air pressure changes and will not be affected by sound vibrations of diaphragm 13'.

Valve 33' will be in closed condition when pumping means 27'' is idle but will commence to open as rod 20 is slowly moved rearward due to the effect of atmospheric

pressure on diaphragm 13' as the air pressure in enclosed space 11 is reduced by said pumping means after it has commenced to operate. The construction of valve means 33' is such that, when it is in intermediate position in its opening movement, the flow of air into enclosed space 11 will become equal to the volumetric displacement of pumping means 27''. In other words, air will enter at the same rate as it is being exhausted. It would be desirable, if the opening motion of valve means 33' could be stopped at precisely the moment when diaphragm 13' has attained its design vibrational mid-position, so as to stabilize the pressure differential, but that is not possible. Consequently, valve 33' will continue to open until more air is being admitted than can be exhausted by constant-speed pumping means such as employed in this instance. As a result, the pressure within enclosed air space 11 will build up until valve means 33' approaches closed condition, whereupon the changed pressure differential will cause re-opening of said valve means. These alternating actions of valve means 33' will produce cyclic displacement of diaphragm 13' similar to that occurring in the embodiments of the invention disclosed in Figs. 1 and 2.

In the embodiment of the invention disclosed in Fig. 3, spring means 24'' constitutes the principal means to offer general resistance to axial displacement of diaphragm 13' by rearward exertion of air pressure thereupon. Instead of using the unsymmetrical negative stiffness device disclosed in Fig. 2 to cancel positive stiffness which opposes vibratory movements of diaphragm 13', a symmetrical negative stiffness device 67 has been incorporated in this third embodiment. This device 67 serves to provide a constant component of axial force to counterbalance the effect of unequal pressure on diaphragm 13' as well as to cancel a portion of the positive air stiffness. In this instance, toggle struts 41'—41', which are force-loaded by springs 46'—46' through the medium of levers 45'—45', are disposed in direct radial relation to rod 20 when in dead-center condition, which corresponds to the design vibrational mid-position of diaphragm 13'. Therefrom, when diaphragm 13' moves either way from this position in its vibrational excursions, axial force components will be exerted by springs 46'—46' on said diaphragm in proportion to the degree of displacement away from mid-position.

It will be understood that it is intended to cover all changes and modifications of the examples of the invention herein chosen for the purpose of illustration which do not constitute departures from the spirit of the invention and scope of the appended claims.

I claim:

1. A loudspeaker comprising: structural means enclosing an air volume; a concavo-convex substantially tensionally inelastic sound reproducing diaphragm resiliently mounted marginally for axial vibration as a unit with one side radiating into the enclosed air volume and the opposite side radiating into the outside atmosphere; transducer means directly connected by substantially tensionally inelastic means to said diaphragm to drive the same in excursions from the design mid-position of its sound vibrations; and means to maintain a constant average pressure differential between the enclosed air volume and the atmosphere in a manner to subject the concave side of the diaphragm to the greater pressure, whereby said diaphragm will be constantly distended in its normal concavo-convex shape.

2. A loudspeaker as defined in claim 1, wherein the diaphragm is of dome shape having spherical curvature.

3. A loudspeaker as defined in claim 1, wherein the diaphragm has substantially the thickness, weight and flexibility of drafting tracing paper.

4. A loudspeaker as defined in claim 1, wherein the diaphragm is made of drafting tracing paper.

5. A loudspeaker as defined in claim 1, wherein the means to maintain the pressure differential is a pump arranged to pump air between the enclosed air volume and

the atmosphere from the convex side of the diaphragm to the concave side thereof; and wherein means is added to create a pressure leakage between the opposite sides of the diaphragm in a direction opposite to the pumping flowage.

6. A loudspeaker as defined in claim 5, wherein means is provided to control the pumping means in a manner to stop the pumped flow of air when the diaphragm reaches the design mid-position of its vibrational excursions.

7. A loudspeaker as defined in claim 6, wherein the pressure leakage means is controllable; and wherein means is added to open the leakage means when the diaphragm moves beyond its design vibrational mid-position.

8. A loudspeaker comprising: structural means enclosing an air volume; a substantially tensionally inelastic sound-reproducing diaphragm resiliently mounted marginally with one side radiating into the enclosed air volume and with its opposite side radiating into the outside atmosphere; transducer means directly connected by tensionally inelastic means to said diaphragm to drive the same in excursions from the design mid-position of its sound vibrations; and means to maintain a pressure differential between the enclosed air volume and the atmosphere in a manner to place the diaphragm under continual tension in one direction only.

9. A loudspeaker as defined in claim 8, wherein means responsive to axial displacement of the diaphragm is added to change the pressure differential whenever the diaphragm is moved by air pressure beyond the design mid-position of its vibrational excursions.

10. A loudspeaker comprising: structural means enclosing an air volume; a sound reproducing diaphragm mounted with one side radiating into the enclosed air volume and with its opposite side radiating into the outside atmosphere; transducer means to drive the diaphragm in excursions between the limits of its sound vibrations and including a magnetic structure and a voice coil arranged in design centered relation to the magnetic field thereof; a reciprocating rod arranged concentric with said voice coil; resilient means supporting the voice coil in its design centered position; resilient means supporting the diaphragm normally in the design vibrational mid-position; means rigidly connecting the diaphragm to the said rod and voice coil; and means to maintain a pressure differential between the enclosed air volume and the atmosphere in a manner to place the diaphragm under continual tension in one direction only.

11. A loudspeaker as defined in claim 10, wherein the diaphragm and rod are connected by flexible members; and wherein spring means is added to exert lengthwise pull on the rod in a direction away from the diaphragm to increase the tension on the connecting members to the degree of rigidity.

12. A loudspeaker as defined in claim 8, wherein there is added spring means to resist pressure influenced axial displacement of the diaphragm.

13. A loudspeaker as defined in claim 12, wherein the spring means is in the form of a positive stiffness negating device including a rod mounted to reciprocate in concentric relation to the diaphragm, means connecting the rod to the diaphragm for substantially rigid movement in synchronism therewith, and spring-loaded toggle means exerting axial components of force on said rod in the direction of vibrational movement of the diaphragm.

14. A loudspeaker as defined in claim 13, wherein the toggle means includes struts that are inclined constantly in one direction to resist air pressure on the diaphragm in the opposite direction.

15. A loudspeaker comprising: structural means enclosing an air volume; a sound reproducing diaphragm mounted with one side radiating into the enclosed air volume and with its opposite side radiating into the out-

side atmosphere; transducer means to drive the diaphragm in excursions from the design mid-position of its sound vibrations; means to pump air between the enclosed air volume and the atmosphere from one side of the diaphragm to the other in a manner to place said diaphragm under continual tension in one direction only; the said structural means having a vent between the enclosed air volume and the atmosphere; valve means controlling said vent; and means responsive to air pressure changes only to open the valve means of the vent whenever the diaphragm is displaced to a predetermined degree by said pressure changes in the direction in which tension is exerted.

16. A loudspeaker as defined in claim 15, wherein the volumetric air displacement by said pumping means and the controlled size of the valve orifice of the vent valve are such that the rate of air evacuation and of inflow will become equal when the valve is opened to a predetermined degree; and wherein when this flow condition has been attained the diaphragm will be in its design vibrational mid-position.

17. A loudspeaker as defined in claim 16, wherein the said predetermined degree of diaphragm displacement will move the diaphragm into coincidence with its design vibrational mid-position.

18. A loudspeaker as defined in claim 17, wherein there is added: spring means to resist pressure-influenced axial displacement of the diaphragm beyond its said design vibrational mid-position.

19. A loudspeaker as defined in claim 18, wherein there is added: a positive stiffness negating device including a rod mounted to reciprocate in concentric relation to the diaphragm; means connecting the rod to the diaphragm for substantially rigid movement in synchronism therewith; and toggle means including plural struts having their inner ends pivotally engaged with said rod and being arranged precisely radial to the latter in dead-center condition when the diaphragm is at the mid-position of its vibrational excursions, and spring-loading means applied to the outer ends of the toggle struts in a manner to exert force thereto in a direction radial to the rod axis, whereby axial components of force will be exerted upon said rod when the diaphragm is vibrationally displaced in either direction under the influence of the transducer means.

20. A loudspeaker as defined in claim 19, wherein there is added: spring means operating the vent valve upon said rod; and a block-like member of considerable mass affixed to said vent valve, whereby the inertia of said member and the resilience of said spring means will prevent said valve from responding to transducer-influenced vibrational movements of the diaphragm.

21. A loudspeaker comprising: structural means enclosing an air volume; plural substantially tensionally inelastic concavo-convex sound reproducing diaphragms resiliently mounted marginally for axial vibration as cooperative units with one side of each radiating into the enclosed air volume and the opposite side radiating into the outside atmosphere; transducer means directly connected by substantially tensionally inelastic means to each diaphragm to drive the same in excursions from the design mid-position of its sound vibrations; and means to maintain a constant average pressure differential between the enclosed air volume and the atmosphere in a manner to subject the concave side of each diaphragm to the greater pressure, whereby the said diaphragms will be constantly distended in their normal concavo-convex shapes.

References Cited in the file of this patent

UNITED STATES PATENTS

1,730,528	Robbins	Oct. 8, 1929
2,713,396	Tavares	July 19, 1955